

Distribution of pacinian corpuscles in the hand of the monkey, *Macaca fuscata*

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ABSTRACT

The size and distribution of pacinian corpuscles were investigated in the palmar aspect of both hands of the monkey, *Macaca fuscata*. Most pacinian corpuscles were located in the dermis (dermal type) and subcutaneous tissue (subcutaneous type) throughout the hand. On light microscopy there were no differences in the structure of these 2 types, although almost all the subcutaneous type had a greater longitudinal dimension than the dermal type. Corpuscles were oval or elliptical and their longitudinal and transverse dimensions varied from 156 to 2025 μm and 88 to 1240 μm , respectively. Many pacinian corpuscles were in close relation to the small blood vessels, and their diameters were as large as those of capillaries. There were 458 corpuscles (dermal type:subcutaneous type = 140:318) in the right hand and 416 (186:230) in the left hand. About 40% of the corpuscles in each hand were found in the digital region; the remainder were located in the palm. The mean number of corpuscles in each finger was 33 and they were concentrated in the distal and middle phalanges. In the palmar region, most corpuscles were localised in the 2nd and 3rd interdigital eminences and the thenar and hypothenar eminences.

INTRODUCTION

The pacinian corpuscle is a large encapsulated mechanoreceptor distributed in the dermis and subcutaneous tissues, in the connective tissues of the joints, mesentery, mesocolon and pancreas, and in the wall of the urinary bladder (Quilliam, 1966; Hunt, 1974). There have been studies on the distribution and size of the corpuscles (Winkelmann & Osment, 1956; Sato, 1957; Stilwell, 1957; Cauna & Mannan, 1958, 1959; Malinovsky, 1966; Lynn, 1969; Kumamoto et al. 1993*b*), their structure (Polacek & Mazanec, 1956; Pease & Quilliam, 1957; Nishi et al. 1969; Santini et al. 1971; Spencer & Schaumburg, 1973; Ide et al. 1988; Munger et al. 1988; Kumamoto et al. 1993*a*), their development (Cauna & Mannan, 1958, 1959; Zelena, 1978) and the degeneration and/or regeneration of axon terminals after axotomy, crushing or freezing (Korthals et al. 1974; Zelena, 1984; Ide, 1987). Pacinian corpuscles were studied in the fingers of man by Winkelmann & Osment (1956) and Cauna & Mannan (1958) and in the monkey palm by Sato

(1957), but there is no comprehensive study of the distribution of Pacinian corpuscles throughout the primate hand. The purpose of the present investigation is to clarify the detailed distributional characteristics and size of the pacinian corpuscles in the palmar aspect of the monkey hand.

MATERIAL AND METHODS

One male Japanese monkey, *Macaca fuscata*, weighing 7.2 kg was used for this study. Under deep anaesthesia with sodium pentobarbital (50 mg/kg bodyweight), the animal was perfused via the left cardiac ventricle with 10% formaldehyde. After removal of the hands, the superficial tissues of the volar side above the tendons of the digital muscles, the skin and subcutaneous tissue were carefully dissected using a stereomicroscope. The specimen was divided into 10 parts as follows: 5 finger regions and 5 palmar regions. Tissues were dehydrated with an ascending ethanol series and embedded in celloidin. The tissue blocks were cut serially into 20 μm longitudinal

sections on a double cylinder microtome (Yamato, Japan) and stored in 70% ethanol at room temperature until use. The sections were stained with haematoxylin and eosin, dehydrated with an ascending ethanol series, cleared with xylene and mounted in Canada balsam. Serial sections taken at 100 µm intervals were enlarged using a dissecting microscope (Nikon V-10, Japan) to count the number of pacinian corpuscles and map their distribution. The dimensions of the corpuscles were measured in all serial sections with an eyepiece micrometer. Student's *t* test was used to analyse the significance of differences between the values.

RESULTS

On haematoxylin and eosin staining, pacinian corpuscles were readily distinguishable as encapsulated organs consisting of capsule, outer core, inner core and sensory terminal. They showed a wide distribution throughout the dermis (dermal type) and subcutaneous tissues (subcutaneous type; Fig. 1). They were also found among the muscles. Corpuscles of the dermal type were isolated and surrounded by tight connective tissue with their longitudinal axes parallel to the skin surface (Fig. 2). Those of the subcutaneous type formed groups of 2–5, surrounded by adipose tissue and sweat glands. Their longitudinal axes were approximately perpendicular to the skin surface (Fig. 3). In this study, we examined the dermal and subcutaneous corpuscles, since only 3 to 4 corpuscles were found among the muscles of the hypothenar eminence and none in the other muscles, such as the lumbricals or palmar interossei. There were no structural differences between dermal and subcutaneous corpuscles. There were 458 corpuscles in the right hand and 416 in the left. The ratio of the dermal to subcutaneous type was 0.44 (140/318) in the right hand and 0.81 (186/230) in the left (Table 1). About 40% of the corpuscles were found in the finger region (170 in the right hand and 163 in the left) and the rest were in the palmar region (288 in the right hand and 253 in the left). The number of corpuscles in each finger ranged from 23 to 41 with 34 on average in the right hand and from 14 to 45 with 33 on average in the left, their density being greater in the central 3 fingers of both hands. Many corpuscles were concentrated in the distal and middle phalanges and a few were scattered in the proximal phalanx. The dermal type in particular showed a high density in the distal phalanx (Fig. 1, Table 1). The palm of the monkey was divided into 6 areas according to Biebert (1961): 3 interdigital eminences, the thenar eminence, the hypothenar

eminence and a central hollow. Corpuscles in the palmar region were mainly concentrated in the 2nd and 3rd interdigital eminences and in the thenar and hypothenar eminences; about 75% of corpuscles were in the thenar and hypothenar eminences. Over the hand as a whole, corpuscle density was particularly high in the distal phalanx and the thenar, hypothenar and 2nd interdigital eminences. In these areas both dermal and subcutaneous types were highly concentrated (Fig. 1, Table 1).

The corpuscles were oval or elliptical with longitudinal and transverse dimensions ranging from 156 to 2025 µm and 88 to 1240 µm, respectively. As indicated in Table 2, subcutaneous corpuscles tended to be of greater length than those in the dermis; the difference was significant between corpuscles in the finger region.

Although a few subcutaneous corpuscles were found near a large nerve bundle (Fig. 4), they were generally not observed along the course of large nerves, such as the palmar digital nerves (Fig. 1). About 85 to 95% of all corpuscles in the hand were found in relation to very small blood vessels (Figs 2–5), although a few subcutaneous ones were in close relation to a large artery or vein (Figs 4, 5). There were no corpuscles showing intimate contact with large blood vessels in either the dermis or subcutaneous tissues.

DISCUSSION

Distributional patterns and size of pacinian corpuscles were investigated in the palmar aspect of the monkey hand in this study. Cauna & Mannan (1958) found that these corpuscles were located in the dermis and subcutaneous tissues and were adjacent to the periosteum or the tendons of flexor digitorum and the short digital muscles in the human hand. They observed 178 corpuscles in the lateral half of a fetal index finger. We previously reported that the total number of pacinian corpuscles was 667 in the cat forefoot and that they showed a predominant localisation in the skin folds (Kumamoto et al. 1993*b*). In the present study, 458 pacinian corpuscles (right hand) and 416 (left hand) were found in the dermis and subcutaneous tissue in the monkey. About 40% were in the digital region, and the remainder were in the palmar region. The average number of corpuscles per finger was 33. This is fewer than the number found in the human fetal finger, although the fingers of these 2 species have much the same length. In the monkey, the corpuscles are concentrated in the distal and middle phalangeal areas, the 2nd and 3rd interdigital

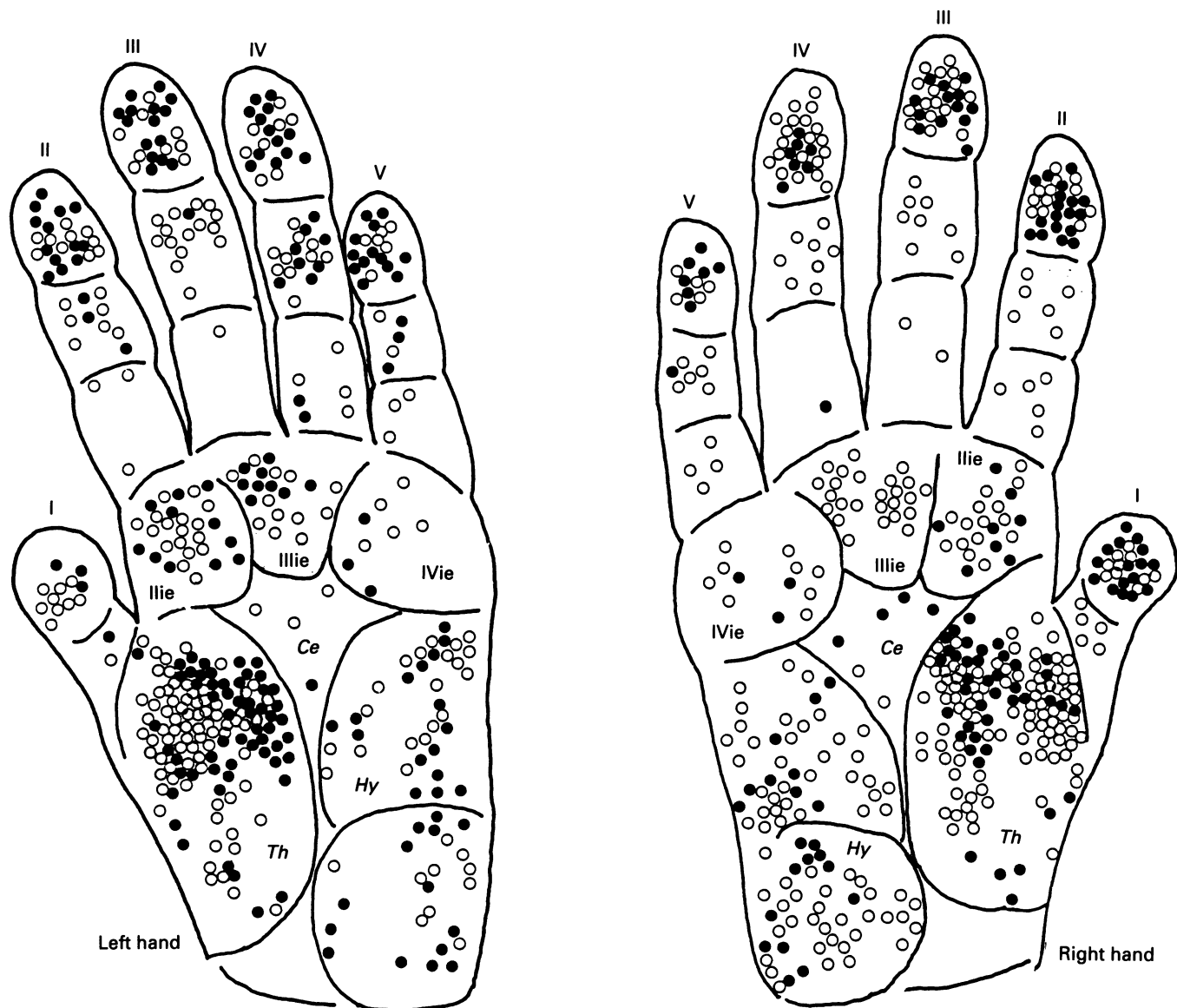


Fig. 1. Schematic drawing depicting the approximate topography of pacinian corpuscles in the dermis (solid circles) and subcutaneous tissue (open circles) of the monkey hand. Many corpuscles are found in the proximal phalangeal area, the 2nd and 3rd interdigital eminences and the thenar and hypothenar eminences. Each circle indicates a single corpuscle. I-V, 1st-5th fingers; IIie-IVie, 2nd-4th interdigital eminences; Th, thenar eminence; Ce, central hollow; Hy, hypothenar eminence.

eminences and the thenar and hypothenar eminences. It is assumed that these localisation characteristics for pacinian corpuscles conform to the functions of the monkey hand, such as gripping, which is a particular characteristic of the primate hand. Moreover, the corpuscles have been observed to respond to very small amplitudes (less than $1\ \mu\text{m}$) of contact or vibration (Hunt, 1974). The high density of dermal corpuscles in the monkey distal phalanx suggests that these portions are sensitive to subtle mechanical stimuli delivered to the skin surface.

Winkelman & Osment (1956) reported that the average length and width of the corpuscles in the human finger tip were $510\ \mu\text{m}$ and $440\ \mu\text{m}$ using paraffin sections. Cauna & Mannan (1958) found that

the average length of the corpuscles in paraffin sections ranged from 500 to $700\ \mu\text{m}$ in the finger of a human newborn and that these corpuscles gradually increased in size to 3 or $4\ \text{mm}$. With allowances for shrinkage during embedding and for species differences, the average corpuscle size in the monkey is in accord with that in the human finger tip and the finger of newborn, but was less than $3\ \text{mm}$. The length of subcutaneous corpuscles was larger than that of those in the dermis. It is possible that retrograde and appositional growth of corpuscles after birth, as described by Cauna & Mannan (1958), can be accomplished more readily within the loose connective tissue of the subcutis than in the tight connective tissue of the dermis.

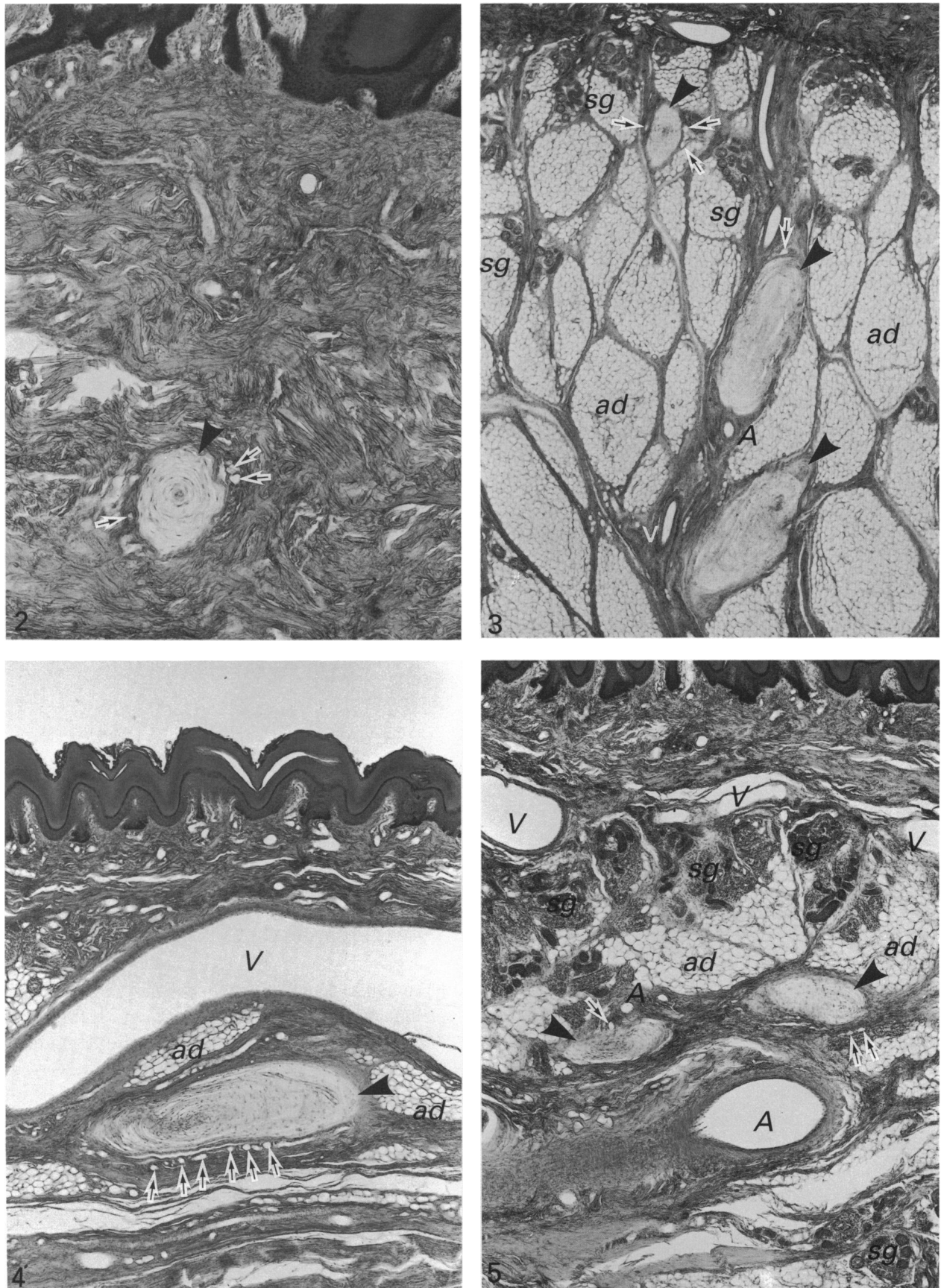


Fig. 2. Dermal pacinian corpuscle. In the dermis of the monkey hand, a pacinian corpuscle (arrow head) is surrounded by tight connective tissue and small blood vessels (arrows) running in close proximity to the corpuscle. $\times 66$.

Table 1. Number of pacinian corpuscles in the dermis and subcutaneous tissues of the monkey hand

Finger region	Left hand							Right hand						
		I	II	III	IV	V	Subtotal		V	IV	III	II	I	Subtotal
Distal phalanx	D	3	13	15	13	13	57	D	7	7	13	18	16	61
	S	9	10	9	8	6	42	S	5	20	16	12	10	63
Subtotal		12	23	24	21	19	99		12	27	29	30	26	124
Middle phalanx	D	—	3	1	8	3	15	D	1	0	0	0	—	1
	S	—	7	15	10	2	34	S	6	8	8	6	—	28
Subtotal		—	10	16	18	5	49		7	8	8	6	—	29
Proximal phalanx	D	1	0	0	2	0	3	D	0	1	0	0	0	1
	S	1	3	1	4	3	12	S	4	0	2	5	5	16
Subtotal		2	3	1	6	3	15		4	1	2	5	5	17
Subtotal	D	4	16	16	23	16	75	D	8	8	13	18	16	63
	S	10	20	25	22	11	88	S	15	28	26	23	15	107
Total		14	36	41	45	27	163		23	36	39	41	31	170
Palmar region														
Intradigital eminence		II		III		IV	Subtotal		IV		III		II	Subtotal
	D	11		9		3	23	D	3		0		8	11
	S	17		12		5	34	S	9		25		15	49
Subtotal		28		21		8	57		12		25		23	60
		Thenar eminence		Central hollow		Hypothenar eminence			Hypothenar eminence		Central hollow		Thenar eminence	
	D	57		1		30	88	D	21		4		41	66
	S	75		3		30	108	S	66		2		94	162
Subtotal		132		4		60	196		87		6		135	228
Subtotal	D						111	D						77
	S						142	S						211
Total							253							288

D, dermal; S, subcutaneous.

Table 2. Mean diameters of pacinian corpuscles in the monkey hand

		Left hand		Right hand	
		L	T	L	T
Finger region	D	414.4 ± 197.3	209.3 ± 78.1	441.7 ± 183.2	274.7 ± 81.4
	S	518.3 ± 250.6**	245.8 ± 105.3*	549.1 ± 240.5**	283.6 ± 114.0
	M	470.5 ± 256.3	229.5 ± 98.9	506.7 ± 227.2	280.3 ± 104.5
Palmar region	D	601.8 ± 264.8	318.9 ± 78.1	635.2 ± 251.1	378.4 ± 142.4
	S	787.7 ± 355.5**	413.5 ± 188.5**	704.9 ± 335.7	388.7 ± 175.9
	M	703.3 ± 335.1	376.9 ± 178.7	666.1 ± 340.1	386.6 ± 174.3

Values represent mean ± S.D. (µm). D, dermis; S, subcutaneous tissue; M, mean value; L, length; T, width. * $P < 0.05$, ** $P < 0.01$.

Pacian corpuscles are responsive to vibration (Gray & Malcolm, 1950; Gray & Matthews, 1951) and maintain a complex association with the glom-

erular arteriovenous anastomoses, signalling changes in local blood supply (Cauna & Mannan, 1958, 1959). Gammon & Bronk (1935) reported that an elevation

Fig. 3. Subcutaneous pacinian corpuscles. Three corpuscles (arrowheads) are present within adipose tissue. The lower 2 corpuscles adjoin a small artery (A) and vein (V). The small upper corpuscle is in close relation to sweat glands (sg) and fine blood vessels (arrows). The longitudinal axes of the lower 2 corpuscles seem to be perpendicular to the skin surface. A, artery; ad, adipose tissue; V, vein. × 24.

Fig. 4. Pacinian corpuscle (arrowhead) located parallel to the skin surface in the subcutaneous tissue of the middle phalanx. All corpuscles in the phalangeal area show the same locational features as this figure. Many small blood vessels (arrows) are adjacent to the corpuscle. V, vein; ad, Adipose tissue. × 40.

Fig. 5. Two pacinian corpuscles (arrowheads) are seen in relation to arteries (A) and fine blood vessels (arrows) in subcutaneous tissue. V, vein; ad, adipose tissue; sg, sweat gland. × 40.

of intravascular pressure effectively stimulated pacinian corpuscles in close relation to the blood vessels of the mesentery of the cat, and that the receptor signalled the degree of distention in the mesenteric vessels. In the monkey hand, however, most of the corpuscles are not in close relation to large blood vessels, but with very small blood vessels or capillaries. These blood vessels are not sufficiently large for pressure from their distention to be capable of evoking a discharge in pacinian corpuscles. Single unit impulses from mechanoreceptors containing pacinian corpuscles were recorded physiologically by stimulation of the glabrous skin of the human hand and the receptive fields of the corpuscles in the skin were examined (Johansson & Vallbo, 1979). This result suggests that pacinian corpuscles in the monkey hand are receptors of external vibratory stimuli.

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